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(54) **COMPRESSED GAS SUPPLY UNIT**

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(51) **Int. Cl.**

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F04B 49/20	(2006.01)
F04C 23/00	(2006.01)
F04C 11/00	(2006.01)
F04C 28/02	(2006.01)
F04C 18/02	(2006.01)
F04B 49/08	(2006.01)
F04B 23/04	(2006.01)
F04C 14/02	(2006.01)
F04B 49/00	(2006.01)

(52) **U.S. Cl.**

CPC ***F04C 23/001*** (2013.01); ***F04B 49/20*** (2013.01); ***F04C 11/001*** (2013.01); ***F04C 18/0207*** (2013.01); ***F04C 28/02*** (2013.01); ***F04C 28/08*** (2013.01); *F04B 23/04* (2013.01); *F04B 49/00* (2013.01); *F04B 49/08* (2013.01); *F04C 14/02* (2013.01); *F04C 2240/403* (2013.01); *F04C 2270/0525* (2013.01)

(58) **Field of Classification Search**

CPC F04B 23/04; F04B 49/00; F04B 49/20; F04B 49/08; F04C 11/00; F04C 14/02

See application file for complete search history.

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(57) **ABSTRACT**

A compressed gas supply unit has scroll compressors. Gas discharged from the scroll compressors travels through a main supply passage and is reserved in a reservoir tank, after which the gas is supplied to a gas recipient from a supply passage. The scroll compressors include inverter devices that allow for independent modulation of the speeds of respective drive motors. The controller includes a speed range setting unit that sets an upper speed limit and a lower speed limit of the scroll compressors, a speed sum calculating unit that calculates a sum of speeds of the scroll compressors based on a load of the compressed gas supply unit, and a speed setting unit that allocates the calculated sum of speeds among the scroll compressors to set speeds for scroll compressors respectively.

4 Claims, 4 Drawing Sheets

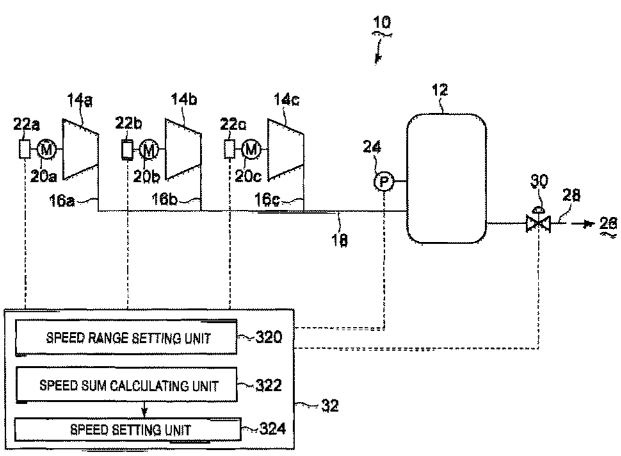

Fig.1

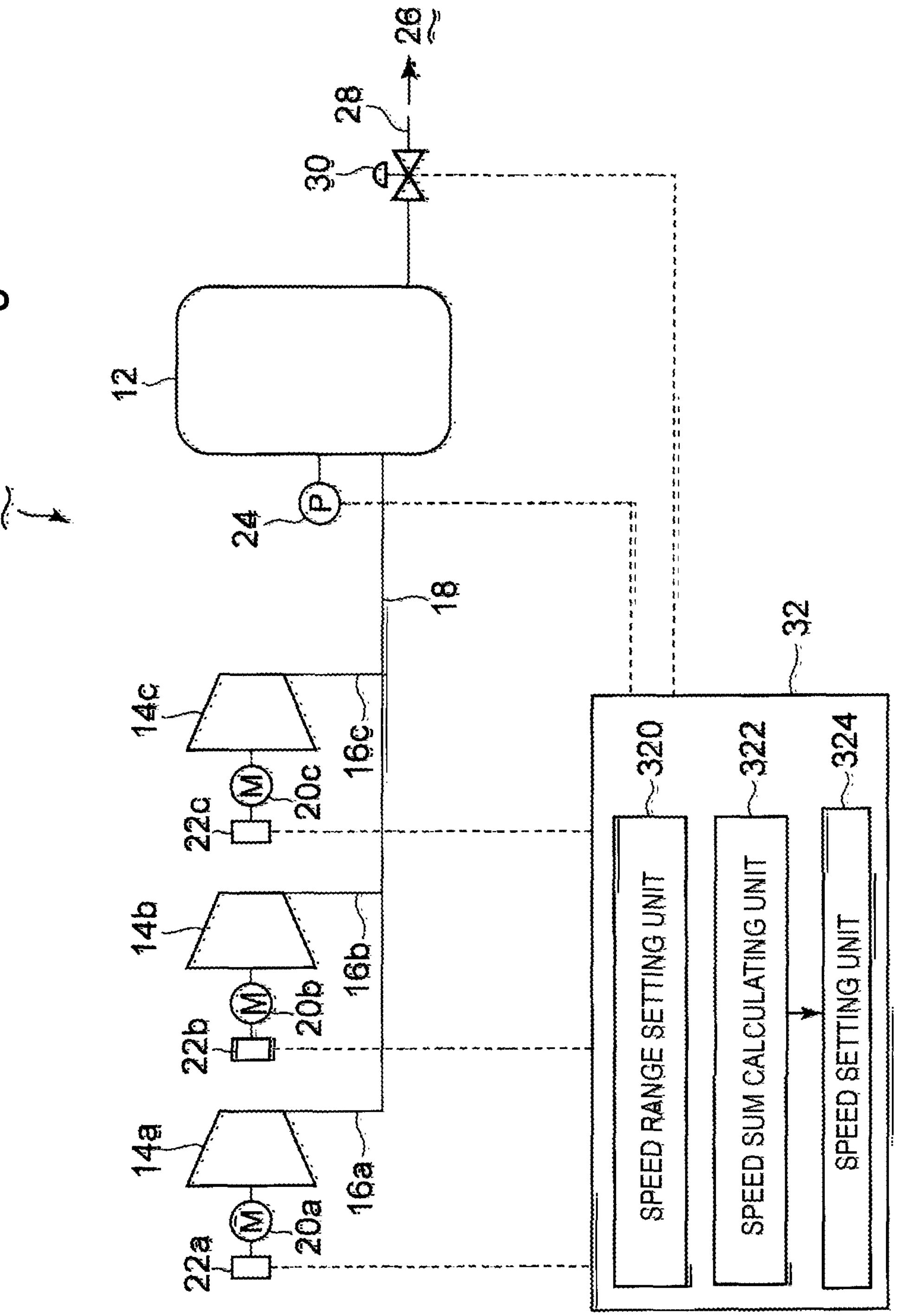
10
12
24
P
30
28
26
18
14a
14b
14c
16a
16b
16c
20a
20b
20c
M
M
M
22a
22b
22c
32
320
322
324
SPEED RANGE SETTING UNIT
SPEED SUM CALCULATING UNIT
SPEED SETTING UNIT

Fig. 2

(A)

VARIABLE SPEED + START/STOP CONTROL OF PLURAL UNITS (PRESENT INVENTION)	SPEED	1st UNIT 14a	%	0	0	0	0	0	0	0	0	30	50	70	90	100
		2nd UNIT 14b		0	0	0	0	30	50	70	90	100	100	100	100	100
		3rd UNIT 14c		30	50	70	90	100	100	100	100	100	100	100	100	100
		OVERALL		10	17	23	30	43	50	57	63	77	83	90	97	100
	SPECIFIC ENERGY	1st UNIT 14a	J/L	0	0	0	0	0	0	0	0	1200	1000	800	600	500
		2nd UNIT 14b		0	0	0	0	1200	1000	800	600	500	500	500	500	500
		3rd UNIT 14c		1200	1000	800	600	500	500	500	500	500	500	500	500	500
		OVERALL		1200	1000	800	600	662	667	624	547	591	600	578	531	500

(B)

SPEED CONTROL OF SINGLE UNIT (CONVENTIONAL METHOD)	SPEED	%	30	40	50	60	70	80	100
	SPECIFIC ENERGY	J/L	1200	1100	1000	900	800	700	500

(C)

VARIABLE SPEED CONTROL ONLY OF PLURAL UNITS (COMPARATIVE EXAMPLE)	SPEED	1st UNIT 14a	%	30	30	30	30	30	30	30	30	30	50	70	90	100
		2nd UNIT 14b		30	30	30	30	30	50	70	90	100	100	100	100	100
		3rd UNIT 14c		30	50	70	90	100	100	100	100	100	100	100	100	100
		OVERALL		30	37	43	50	53	60	67	73	77	83	90	97	100
	SPECIFIC ENERGY	1st UNIT 14a	J/L	1200	1200	1200	1200	1200	1200	1200	1200	1200	1000	800	600	500
		2nd UNIT 14b		1200	1200	1200	1200	1200	1000	800	600	500	500	500	500	500
		3rd UNIT 14c		1200	1000	800	600	500	500	500	500	500	500	500	500	500
		OVERALL		1200	1109	985	840	763	756	710	636	591	600	578	531	500

Fig. 3

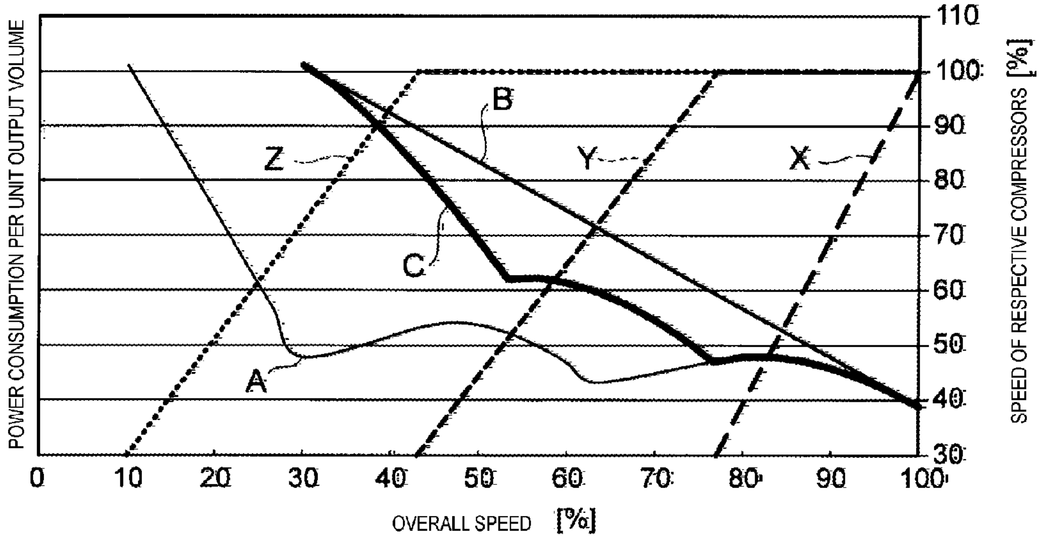
POWER CONSUMPTION PER UNIT OUTPUT VOLUME
SPEED OF RESPECTIVE COMPRESSORS [%]
OVERALL SPEED [%]
A
B
C
X
Y
Z
0
10
20
30
40
50
60
70
80
90
100
110

Fig. 4

$MV_{min}=1000$, $MV_{max}=3000$

OVERALL SPEED	ALLOCATION		
	1st UNIT 14a	2nd UNIT 14b	3rd UNIT 14c
MV [min⁻¹]	MV_1 [min⁻¹]	MV_2 [min⁻¹]	MV_3 [min⁻¹]
0	0	0	0
100	0	0	0
900	0	0	0
1000	1000	0	0
1500	1500	0	0
2000	2000	0	0
2500	2500	0	0
3000	3000	0	0
3500	2500	1000	0
4000	3000	1000	0
4500	3000	1500	0
5000	3000	2000	0
5500	3000	2500	0
6000	3000	3000	0
6500	3000	2500	1000
7000	3000	3000	1000
7500	3000	3000	1500
8000	3000	3000	2000
8500	3000	3000	2500
9000	3000	3000	3000

COMPRESSED GAS SUPPLY UNIT

RELATED APPLICATIONS

The present application is based on, and claims priority from, Japanese Application Number 2012-104136, filed Apr. 27, 2012, the disclosure of which is hereby incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a compressed gas supply unit having a plurality of scroll compressors and capable of maintaining stable operation even under frequently changing loads.

2. Description of the Related Art

If a compressed gas supply unit has only one compressor, the compressed gas supply unit may become unable to produce and supply compressed gas to a gas recipient, should a failure occur in this one compressor. Thus, compressed gas supply units having a plurality of compressors which are capable of controlling the number of compressors under operation in accordance with the load (demand for compressed gas) to supply compressed gas as required by the gas recipient are known. Such compressed gas supply units achieve energy savings by controlling and minimizing the number of compressors under operation.

Japanese Patent Application Laid-open No. 2010-190197 discloses a compressed gas supply unit including a common reservoir tank for reserving gas discharged from a plurality of compressors, and a pressure sensor for detecting the pressure in the reservoir tank, wherein the number of compressors under operation is controlled in accordance with changes in the amount of consumed gas, which are determined from measurements by the pressure sensor of the pressure in the reservoir tank.

Conventional compressed gas supply units having a plurality of compressors can supply compressed gas to the gas recipient at a level required by the gas recipient by maintaining the pressure in the merge pipe on the discharge side of the compressors or the reservoir tank in accordance with load change (demand for compressed gas) at the required level. Thus, inverter devices that allow variation of compressor speed are provided. The inverter devices modulate the speeds of the compressors and adjust the pressure on the discharge side of the compressors to the level required by the gas recipient. One problem here is power consumption which increases because of poor efficiency caused by low speed operation, which is necessary to adapt to low load of the compressed air supply units.

Japanese Patent Application Laid-open No. H11-343986 discloses a compressed air production apparatus, having a plurality of motor-driven screw compressors arranged in parallel rows, and the respective discharge air systems merged into one pipe or air tank. This compressed air production apparatus includes an inverter device that allows for variable speed modulation of the motors for the respective screw compressors, a pressure sensor provided in the merge pipe or air tank, and a controller that controls the plurality of screw compressors to keep the pressure detected by the pressure sensor within a range of predetermined upper and lower pressure limits. The controller controls to operate only one of the plurality of screw compressors at varying speeds by means of the inverter device, while other screw compressors are either operated under full load conditions, or stopped. Thereby this compressed air production apparatus reduces power consumption, as making it substantially linearly proportional to the amount of air being used.

The compressed air production apparatus disclosed in Japanese Patent Application Laid-open No. H11-343986 enables a reduction in power consumption as compared to simple speed modulation of a plurality of compressors. However, under frequently changing loads, the apparatus is not capable of modulating the speeds of the respective compressors immediately in response to a load change to stably maintain the discharge pressure of the compressors at a level required by the gas recipient.

Scroll compressors offer merits of small size, light weight, low vibration and noise, lower in component count, and ease of production, and have found wide applications as small compressors in vehicle air conditioning compressor, superchargers, and the like. The scroll compressors can promptly react to frequent load changes by being used in combination with inverter devices, as their speed-torque characteristics are suited to variable speed drive by inverter devices.

SUMMARY OF THE INVENTION

In view of the problems in the conventional techniques, an object of the present invention is to allow for prompt reaction to frequent load changes to enable stable adjustment of the discharge pressure of compressed gas to a level required by a gas recipient and reduction of power consumption, in a compressed gas supply unit with a multiple compressor system that uses scroll compressors.

The compressed gas supply unit of the present invention includes a plurality of scroll compressors, an inverter device allowing independent modulation of speeds of the respective scroll compressors, a merge pipe or a reservoir tank for collecting gas discharged from the plurality of scroll compressors, a pressure sensor that detects discharge pressure of the plurality of scroll compressors, and a controller that controls the inverter device for modulating the speeds of the respective scroll compressors.

The controller includes a speed range setting unit that sets an upper speed limit and a lower speed limit of the plurality of scroll compressors, a calculating un it that calculates a sum of speeds of the plurality of scroll compressors based on a load of the compressed gas supply unit, and a speed setting unit that allocates the calculated sum of speeds among the scroll compressors to set speeds for the respective scroll compressors.

The speed range setting unit sets an upper speed limit of the scroll compressors to exclude speeds at which the motors that drive the scroll compressors will be overloaded and cannot run correctly. A lower speed limit is also set so as to exclude low speeds at which the specific energy (power consumption/discharge volume) becomes extremely large. The calculating unit calculates the sum of speeds of the plurality of scroll compressors based on the load of the compressed gas supply unit, and the speed setting unit allocates the calculated sum of speeds among the scroll compressors to set the speeds for the respective scroll compressors.

Thereby, the speeds of the scroll compressors can be kept within a range where they run correctly with low power consumption. Also, as the speed of each scroll compressor can be set in an early stage adapted to the load of the compressed gas supply unit, the discharge pressure of the compressed gas can be adjusted promptly to a desired level for the gas recipient in a stable manner.

When the sum of speeds calculated by the calculating unit is lower than a sum of upper speed limits of all the scroll compressors, the speed setting unit reduces the speed of a first scroll compressor by a difference between the calculated sum of speeds and the sum of upper speed limits, and sets the speeds of other scroll compressors to the upper speed limit. When the aforesaid difference exceeds the upper speed limit of the first scroll compressor, the speed setting unit stops the first scroll compressor, and reduces the speed of a second scroll compressor by a difference between the aforementioned difference and the upper speed limit of the first scroll compressor. Thus only some of the scroll compressors are run at a low speed while other scroll compressors are run at a high speed, whereby the specific energy of the compressed gas supply unit can be reduced.

As described above, the present invention allows for use of scroll compressors that are suited for applications where their speeds need to be changed frequently, and setting of the speed of each scroll compressor in prompt reaction to frequent load changes. Thus a compressed gas supply unit capable of stably adjusting the discharge pressure of compressed gas to a level required by the gas recipient and reducing power consumption despite frequent load changes can be realized.

Preferably, in the present invention, when the difference between the calculated sum of speeds and the sum of upper speed limits is larger than the difference between the upper speed limit and the lower speed limit of the first scroll compressor (The second difference), and smaller than the upper speed limit of the first scroll compressor, the speed setting unit sets the speed of the first scroll compressor to the lower speed limit, and reduces the speed of the second scroll compressor by a difference between the aforementioned difference and the second difference. Thereby, the number of scroll compressors run at a low speed is reduced, so that the power consumption is lower, and also the sum of speeds of all the scroll compressors can be easily matched with the calculated sum of speeds.

Oil-free scroll compressors are used in a variety of applications as they can supply clean air completely free of oil mist. On the other hand, oil-free compressors are prone to formation of a clearance in compression chambers, which lowers the compressor efficiency due to leakage of compressed gas through the clearance. This tendency is more evident during low speed operation. It is therefore preferable to set the lower speed limit for oil-free operation of scroll compressors to be higher than the lower speed limit for lubricated operation. Thereby, a drop in efficiency of the scroll compressors during oil-free operation can be prevented to suppress an increase in power consumption.

According to the present invention, the controller that modulates the speeds of the plurality of scroll compressors includes a speed range setting unit, a calculating unit that calculates the sum of speeds of the plurality of scroll compressors, and a speed setting unit that sets the speed of each scroll compressor based on the calculated sum of speeds. The controller can promptly set the speeds of the respective scroll compressors in response to frequent load changes, thereby stably adjusting the discharge pressure of compressed gas promptly to a level required by a gas recipient. Since only some of the scroll compressors are run at a low speed while other scroll compressors are run at a high speed, the specific energy of the compressed gas supply unit can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a system diagram of a compressed gas supply unit according to a first embodiment of the present invention;

FIG. **2**A is a chart showing a control method of the first embodiment, FIG. **2**B is a chart showing a control method of a comparative example, and FIG. **2**C is a chart showing a conventional method of using a single compressor and controlling its speed;

FIG. **3** is a graph showing the power consumption in the cases with the first embodiment, the comparative example, and the conventional method shown in FIGS. **2**A to **2**C; and

FIG. **4** is a chart showing a control method according to a second embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The illustrated embodiments of the present invention will be hereinafter described in detail. It should be noted that, unless otherwise particularly specified, the sizes, materials, shapes, and relative arrangement or the like of constituent components described in these embodiments are not intended to limit the scope of this invention.

Embodiment 1

A first embodiment in which the present invention is applied to a compressed gas supply unit equipped with oil-free scroll air compressors will be described with reference to FIG. **1** to FIG. **3**. In FIG. **1**, the compressed gas supply unit **10** includes one reservoir tank **12** and three scroll compressors **14***a* to **14***c*. The discharge passages **16***a* to **16***c* of the respective scroll compressors **14***a* to **14***c* join a main supply passage **18**, which is connected to the reservoir tank **12**. Compressed gas discharged from the respective scroll compressors **14***a* to **14***c* travels through the main supply passage **18** and is reserved temporarily in the reservoir tank **12**.

The scroll compressors **14***a* to **14***c* each include a drive motor **20***a* to **20***c*, and an inverter device **22***a* to **22***c* that allows for independent and stepless modulation of the speed of the drive motor **20***a* to **20***c*. In the reservoir tank **12** is provided a pressure sensor **24** that detects the pressure of compressed gas inside the reservoir tank **12**. A supply passage **28**, with a solenoid valve **30**, is provided to the reservoir tank **12** for supplying compressed gas to a gas recipient **26**.

A controller **32** is located in a monitor room (not shown), and measurements from the pressure sensor **24** are sent to the controller **32**. The controller **32** controls the inverter devices **22***a* to **22***c* to modulate the speeds of the scroll compressors **14***a* to **14***c*, as well as the on/off of the solenoid valve **30**. The controller **32** adjusts the pressure of compressed gas in the reservoir tank **12** always to the level required by the gas recipient **26**.

The controller **32** includes a speed range setting unit **320** that sets an upper speed limit and a lower speed limit of the scroll compressors **14***a* to **14***c*, a speed sum calculating unit **322** calculating a sum of speeds of the respective scroll compressors **14***a* to **14***c* based on adapted to a load of the compressed gas supply unit **10**, and a speed setting unit **324** that allocates the calculated sum of speeds among the scroll compressors to set the speeds for the respective scroll compressors.

FIGS. **2**A to **2**C more specifically show how the scroll compressors **14***a* to **14***c* are controlled, in the present invention, with a conventional method and in a comparative example. FIGS. **2**A to **2**C show the speeds of the respective scroll compressors **14***a* to **14***c*, and specific energy (power consumption per unit discharge volume) of the drive motors **20***a* to **20***c* adapted to these speeds. The speeds are shown in percentage and not as absolute values. For example, "50%

speed" represents the speed of the drive motor **20**_a_ to **20**_c_ that is required when the load percentage of the scroll compressors **14**_a_ to **14**_c_ is 50%. The overall speed (%) represents a value obtained by dividing the sum of speeds (%) of the scroll compressors **14**_a_ to **14**_c_ by the number of the scroll compressors **14**_a_ to **14**_c_.

In this embodiment, the upper speed limit (100%) set by the speed range setting unit **320** is the speed of the drive motor **20**_a_ to **20**_c_ when the load percentage of the scroll compressor **14**_a_ to **14**_c_ is 100%. This prevents the speeds of the drive motors **20**_a_ to **20**_c_ from being in a range to be overloaded and maintains the motors to run correctly. The lower speed limit is provided in relation to the specific energy, as the specific energy of the drive motors **20**_a_ to **20**_c_ increases extremely in a low speed range. The speed range setting unit **320** sets a speed of 30% corresponding to the load percentage of 30% as the lower speed limit.

The speed sum calculating unit **322** calculates the sum of speeds of the respective scroll compressors **14**_a_ to **14**_c_ based on and adapted to the load percentage of the compressed gas supply unit **10**. The speed setting unit **324** allocates this sum of speeds calculated by the speed sum calculating unit **322** among the scroll compressors **14**_a_ to **14**_c_, thus setting the speeds for the respective scroll compressors **14**_a_ to **14**_c_.

FIG. **2**A is a chart showing a method of controlling the scroll compressors **14**_a_ to **14**_c_ according to the present invention. In FIG. **2**A, for example, when the load percentage of the compressed gas supply unit **10** is 100%, the overall speed is 100%, too, and the sum of speeds calculated by the speed sum calculating unit **322** is 300%. The speed setting unit **324** allocates 100% of this speed sum to each of the scroll compressors **14**_a_ to **14**_c_, thus setting the speed for each scroll compressor **14**_a_ to **14**_c_. When the load percentage of the compressed gas supply unit **10** is 97%, the overall speed is 97%, too, and the sum of speeds is 290%. Of this speed sum, 90% is allocated to a first unit **14**_a_, and 100% is allocated to second and third units **14**_b_ and **14**_c_. As the overall load percentage decreases from 100%, the speed of only the first unit **14**_a_ is reduced.

As the load percentage of the compressed gas supply unit **10** lowers, the first unit **14**_a_ only is reduced in speed, to the lower speed limit which is 30%. When the load percentage lowers further than that, the first unit **14**_a_ is stopped, and if the load becomes still lower, the speed of the second unit **14**_b_ is reduced. For example, when the load percentage is 63%, the first unit **14**_a_ is stopped, and the speed of the second unit **14**_b_ is lowered to 90%. When the load percentage decreases further, the speed of the second unit **14**_b_ is reduced further. When the load percentage decreases as low as to 43% (overall speed: 43%), the speed of the second unit **14**_b_ is lowered to 30%, after which, if the load percentage lowers further, the second unit **14**_b_ is stopped, and the speed of the third unit **14**_c_ is reduced.

FIG. **2**B shows a conventional control method wherein one scroll compressor is used and the speed of this scroll compressor is modulated. FIG. **2**C shows another control method (comparative example) for a compressed gas supply unit having three scroll compressors, which does not involve start-stop control of the compressors but only the speed control of the three scroll compressors. In this comparative example, as the load percentage of the compressed gas supply unit **10** lowers, the speed of only the first unit **14**_a_ is reduced to the lower speed limit, which is 30%. When the load percentage lowers further, the speed of the second unit **14**_b_ is reduced gradually to 30%. When the load percentage lowers further, the speed of the third unit **14**_c_ is reduced gradually to 30%. The difference from the embodiment shown in FIG. **2**A is that the speeds of the respective scroll compressors are not reduced to lower than 30%.

FIG. **3** is a graph drawn by plotting the values shown in the charts of FIG. **2**A, FIG. **2**B, and FIG. **2**C. The horizontal axis represents the overall speed (%), while the vertical axis represents the specific energy (power consumption per unit discharge volume) of the drive motors **20**_a_ to **20**_c_, or the speed (%) of the respective scroll compressors **14**_a_ to **14**_c_. The speed (%) primarily corresponds to the load percentage (%). Namely, when the load percentage is 30%, the speed is also 30%. In FIG. **3**, line A indicates the control method of this embodiment, line B indicates the conventional control method shown in FIG. **2**B, and line C indicates the control method of the comparative example shown in FIG. **2**C. Line X represents the first unit **14**_a_, line Y represents the second unit **14**_b_, and line Z represents the third unit **14**_c_. Data for lower than 30% is not shown, as the scroll compressors **14**_a_ to **14**_c_ are stopped when the speed becomes below 30%.

According to this embodiment, by means of the speed range setting unit **320**, the speeds of the respective scroll compressors **14**_a_ to **14**_c_ are maintained in a range where the drive motors **20**_a_ to **20**_c_ run normally with low specific energy (power consumption per unit discharge volume). With the speed sum calculating unit **322**, the sum of speeds of the scroll compressors **14**_a_ to **14**_c_ is calculated based on and adapted to the current load percentage of the compressed gas supply unit **10**. The speed setting unit **324** allocates the calculated sum of speeds among the scroll compressors **14**_a_ to **14**_c_, whereby the speeds of the respective scroll compressors **14**_a_ to **14**_c_ can be set in an early stage adapted to the load percentage of the compressed gas supply unit **10**. Thus the compressed gas supply unit **10** can promptly adjust the discharge pressure to a desired level and stably supply the compressed gas to the gas recipient **26**.

The speed setting unit **324** sets the speeds of the respective scroll compressors **14**_a_ to **14**_c_ such that only some of them are operated at a low speed, while others are maintained at a high speed, so that the specific energy of the drive motors **20**_a_ to **20**_c_ is reduced. FIG. **3** indicates that the specific energy is significantly reduced in the low speed range with the use of the control method of this embodiment represented by line A, as compared to the conventional method represented by line B and the comparative example represented by line C. With the lower speed limit of 30%, the possibility of leakage of compressed gas from the compression chambers is reduced even during oil-free operation, to achieve good efficiency of operation and suppress an increase in specific energy.

Embodiment 2

Next, a second embodiment of the present invention will be described with reference to FIG. **4**. This embodiment is an example of operating the compressed gas supply unit **10** shown in FIG. **1** in a different manner. In this embodiment, the speed range setting unit **320** sets the lower speed limit MV_{min} to 1000 min^{-1}, and the upper speed limit MV_{max} to 3000 min^{-1}.

In this embodiment, the sum of the upper limit speeds of the scroll compressors **14**_a_ to **14**_c_ is 9000 min^{-1}. When the speed sum is lowered from 9000 min^{-1} to 8500 min^{-1}, the speed of the third unit **14**_c_ is reduced from 3000 min^{-1} to 2500 min^{-1}. Namely, as the speed sum lowers, the speed of only the third unit **14**_c_ is reduced. After the speed of the third unit **14**_c_ reaches the lower speed limit MV_{min}, when the speed sum further lowers by 500 min^{-1}, the speed of the second unit **14**_b_ is lowered by 500 min^{-1}. When the overall speed further lowers by 500 min^{-1}, the speed of the second unit **14***b* is returned to 3000 min^{-1}, and the third unit **14***c* is stopped. When the overall speed further lowers, this time around, the speed of the second unit **14***b* is reduced.

According to this embodiment, in addition to the advantageous effects of the first embodiment, the number of scroll compressors run at low speeds is minimized to reduce the specific energy of the drive motors **20***a* to **20***c*, while it is made easy to modulate the sum of speeds of all the scroll compressors **14***a* to **14***c* to the calculated sum of speeds determined by the speed sum calculating unit **322**.

According to the present invention, a constant discharge pressure is maintained to achieve stable operation and power consumption is reduced despite frequent load changes in a compressed gas supply unit having a plurality of scroll compressors.

What is claimed is:

1. A compressed gas supply unit, comprising: a plurality of scroll compressors, an inverter device allowing independent modulation of speeds of the respective scroll compressors, a merge pipe or a reservoir tank for collecting gas discharged from the plurality of scroll compressors, a pressure sensor detecting discharge pressure of the plurality of scroll compressors, and a controller controlling the inverter device for modulating the speeds of the respective scroll compressors,

the controller including a speed range setting unit that sets an upper speed limit and a lower speed limit of the respective plurality of scroll compressors, a calculating unit that calculates a sum of speeds of the plurality of scroll compressors based on a load of the compressed gas supply unit, and a speed setting unit that allocates the calculated sum of speeds among the scroll compressors to set speeds for the respective scroll compressors, wherein

when the sum of speeds calculated by the calculating unit is lower than a sum of upper speed limits of all the scroll compressors, the speed setting unit reduces the speed of a first scroll compressor by a first difference between the calculated sum of speeds and the sum of upper speed limits, and sets the speeds of the other scroll compressors to the upper speed limit, and when the first difference exceeds the upper speed limit of the first scroll compressor, the speed setting unit stops the first scroll compressor, and reduces the speed of a second scroll compressor by a difference between the first difference and the upper speed limit of the first scroll compressor.

2. The compressed gas supply unit according to claim **1**, wherein when the first difference is larger than a second difference between the upper speed limit and the lower speed limit of the first scroll compressor, and smaller than the upper speed limit of the first scroll compressor, the speed setting unit sets the speed of the first scroll compressor to the lower speed limit, and reduces the speed of the second scroll compressor by a difference between the first difference and the second difference.

3. The compressed gas supply unit according to claim **1**, wherein the speed range setting unit sets a lower speed limit for oil-free operation of the scroll compressors to be higher than a lower speed limit for lubricated operation.

4. The compressed gas supply unit according to claim **3**, wherein the lower speed limit for oil-free operation of the scroll compressors is set to a speed adapted to a load percentage of 30% of the scroll compressors.

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